Forum for Surface Water Flooding Issues

29 July 2016 at 10.30 am, Council Chamber, Rayleigh Civic Suite

Agenda

Membership

Cllr T G Cutmore	Cllr Mrs C E Roe
Cllr B T Hazlewood	Cllr D J Sperring
Cllr G J Ioannou	Cllr M J Steptoe
Cllr Mrs J R Lumley	Cllr I H Ward
Cllr R Milne	

1. **Rawreth Brook, Rawreth** – presentation by Phil Garvey, Senior Civil Engineer, Arcadis Consulting (UK) Ltd, on the feasibility study of potential flood alleviation measures for Rawreth Brook.

2. **Agree Minutes of meeting held on 2 October 2015**

3. **Completed Schemes**

4. **Pipeline Projects for Rochford (Hockley project)** - Dave Chapman (ECC)

Essex County Council Highways (ECCH)

5. Warwick Close/Warwick Road – road programmed for resurfacing in 2015/16 (Capital Maintenance team)

6. Laburnum Way, Rayleigh. ECC working on the redesign of the culvert.

7. London Hill, Rayleigh – Flooding at junction of Station Road.

8. High Road, Hockley – ECCH capacity of existing surface water systems.

9. Eastwood Rise, Rayleigh – ECCH clearance of gullies and channel serving the surfaced carriageway.

10. High Street, Rayleigh – ECCH flooding on pedestrian area adjacent water trough.

11. Footpath 5 Little Wakering - ECC public rights of way vegetation clearance and remove rising from the adjacent ditch.

12. Daly’s Road j/w Ashingdon Road, Rochford – highway drainage problem.

Anglian Water Authority (AWA)

13. Flood park Magnolia Public Open Space – clearance of flood park to restore original capacity.

Anglian Water/ECCH

14. 92 Trinity Road – property flooding from highway

Rochford District Council (RDC)

15. Nobles Green ditch, Rayleigh – RDC maintenance works regarding vegetation clearance.

Environmental Agency (EA)/Private Landowners

16. Fairmead, Rayleigh – Rawreth Brook maintenance.

Private Landowners

17. Nelson Road, Rayleigh – private land owners open ditch needs maintenance.

18. Hawkwell Brook – vegetation clearance.

19. The Bull, Main Road Hockley – blocked ditch restricting highway drainage.

20. **Any Other Business**.

MEMO

SUBJECT
Rawreth Brook Modelling Technical Note

DATE
30 June 2016

DEPARTMENT
Water

PROJECT NUMBER
UA008499

FROM
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1. Introduction

In November 2015 Arcadis was instructed by Rochford District Council to undertake a feasibility study in order to alleviated flooding within the village of Rawreth. This technical note provides detail of the modelling approach undertaken as well as details of the modelled results.

2. Available Data

Previously, modelling has been undertaken as part of two previous studies undertaken in 2015 by JBA Consulting and CH2M, details of which are provided below:

- Rawreth Brook Hydraulic Model (JBA, 2015)
  - JBA were commissioned by the Environment Agency (EA) to undertake hydrological and hydraulic modelling on four watercourses, including Rawreth Brook in Essex in November 2015. Following re-designation of these watercourses as main rivers the EA required updated hydraulic models in order to provide an understanding of the flood risk posed by them.
- Battlesbridge Hydraulic Model (CH2M, 2015)
  - CH2M were commissioned by the EA in order to investigate the impact of operation of the Battlesbridge Tide Mill as well as dredging on upstream flood levels in response to flood risk concerns raised by residents of Church Road. This involved modification of the existing JBA model by removing the upstream 1D portions and linking the downstream Rawreth floodplain to 2D and to a portion of the River Crouch model.

It has been assumed that the previously undertaken modelling studies are acceptable for the purposes of this study and have only been subjected to a brief model review.

3. Baseline Modelling

In order to fully assess the entire reach of the Rawreth Brook in the best possible detail the two previous developed models were combined in that the more detailed Battlesbridge section was added to the downstream larger Rawreth Brook model. This combined model was then modified in that the existing Battlesbridge 2D floodplain was extended upstream of Church Road.

Following a site visit, a key structure was identified which had not been schematised as part of the previous modelling work. This was a ditch and associated pipe and flap valve which drains the land of Brookfield Farm.

There at two inflows to the hydraulic model, the first representing the River Crouch fluvial and tidal levels at the downstream end with the second representing the fluvial and surface inflows from the Rawreth Brook. Given that Rawreth village is flooding annual it was decided to apply the River Crouch 50%AEP and Highest Annual Tide levels as the downstream boundary for all design runs.

As agreed with the client the baseline was model was then for the three design events 10% AEP, 2%

AEP and 1% AEP. The results are provided in Figures 1-3 below.

The model results confirmed the anecdotal reports provided by the council that the properties along Church Road do flood even during lower order flood events. No calibration was carried out as this had previously undertaken as part of the previous modelling studies and has been previously approved by the EA.

Figure 1: Baseline: 10% AEP Rawreth Brook, 50% AEP River Crouch and Highest Annual Tide (HAT)

Figure 2: Baseline: 2% AEP Rawreth Brook, 50% AEP River Crouch and HAT

Figure 3: Baseline: 1% AEP Rawreth Brook, 50% AEP River Crouch and HAT

4. Option Modelling

4.1 Option 1: Tidal Control Structure and Flood Storage Area

The previously discussed baseline model was modified to assess the impact of the proposed option. The option was schematised by adding a control structure in the form of a conduit unit and flapped orifice to the confluence of the Rawreth Brook to the River Crouch of dimensions 5m x 1m. Invert levels were taken as existing channel bed levels.

The model was run for the three design events as below:

- 10% AEP Rawreth Brook, 50% AEP River Crouch + Highest Annual Tide
- 2% AEP Rawreth Brook, 50% AEP River Crouch + Highest Annual Tide
- 1% AEP Rawreth Brook, 50% AEP River Crouch + Highest Annual Tide

The results are shown in Figures 4-6 on the page overleaf with discussion of the results available within the main feasibility report.

Figure 4: Option 1: 10% AEP Rawreth Brook, 50% AEP River Crouch and Highest Annual Tide (HAT)

Figure 5: Option 1: 2% AEP Rawreth Brook, 50% AEP River Crouch and HAT

Figure 6: Option 1: 1% AEP Rawreth Brook, 50% AEP River Crouch and HAT

4.2 Option 2: Upstream Control Structure and Flood Storage Area

The previously discussed linked 1D-2D baseline model was used to assess the impact of the proposed option. The option was schematised through the addition of a control structure in the form of a QH relationship designed to restrict peak flows to acceptable levels along with a conduit under Church Road of dimensions 4m x 1.62m. Invert levels were taken as existing channel bed levels. The proposed bund was represented through modification to the existing TUFLOW DEM as a 'z' function of length 740m and a height of 1m. The model was run for the three design events as below:

- 10% AEP Rawreth Brook, 50% AEP River Crouch + Highest Annual Tide
- 2% AEP Rawreth Brook, 50% AEP River Crouch + Highest Annual Tide
- 1% AEP Rawreth Brook, 50% AEP River Crouch + Highest Annual Tide

The results are shown on the page overleaf in Figures 7-9 with discussion of the results available within the main feasibility report.

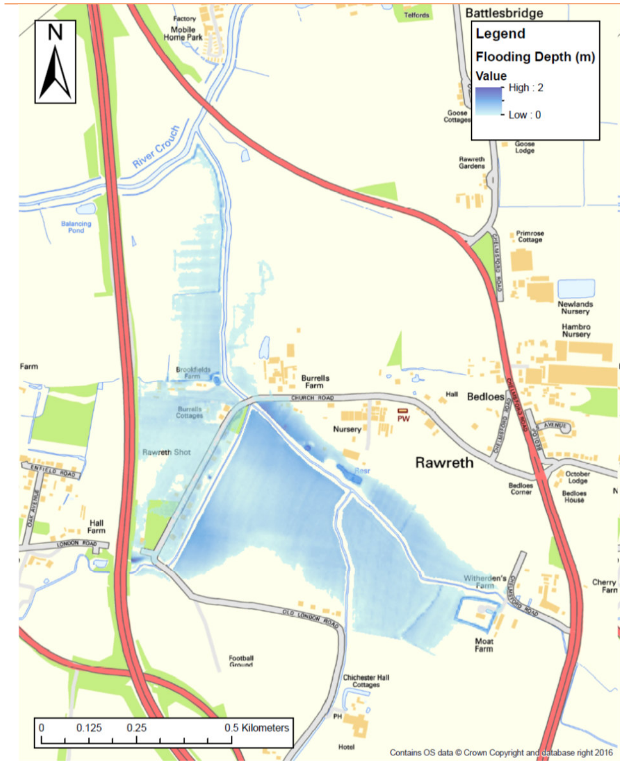

Figure 7: Option 2: 10% AEP Rawreth Brook, 50% AEP River Crouch and Highest Annual Tide (HAT)

Figure 8: Option 2: 2% AEP Rawreth Brook, 50% AEP River Crouch and HAT

Figure 9: Option 2: 1% AEP Rawreth Brook, 50% AEP River Crouch and HAT

4.3 Option 3: Larger Upstream Control Structure and Flood Storage Area with Enlarged Church Road Bridge

The previously discussed linked 1D-2D baseline model was used to assess the impact of the proposed option. The option was schematised through the addition of a control structure in the form of a QH relationship designed to restrict peak flows to acceptable levels along with a conduit under Church Road of dimensions 8m x 1.62m. Invert levels were taken as existing channel bed levels. The proposed bund was represented through modification to the existing TUFLOW DEM as a ‘z’ function of length 740m and a height of 1m.

The model was run for the three design events as below:

- 10% AEP Rawreth Brook, 50% AEP River Crouch + Highest Annual Tide
- 2% AEP Rawreth Brook, 50% AEP River Crouch + Highest Annual Tide
- 1% AEP Rawreth Brook, 50% AEP River Crouch + Highest Annual Tide

The results are shown in Figures 10-12 on the page overleaf with discussion of the results available within the main feasibility report.

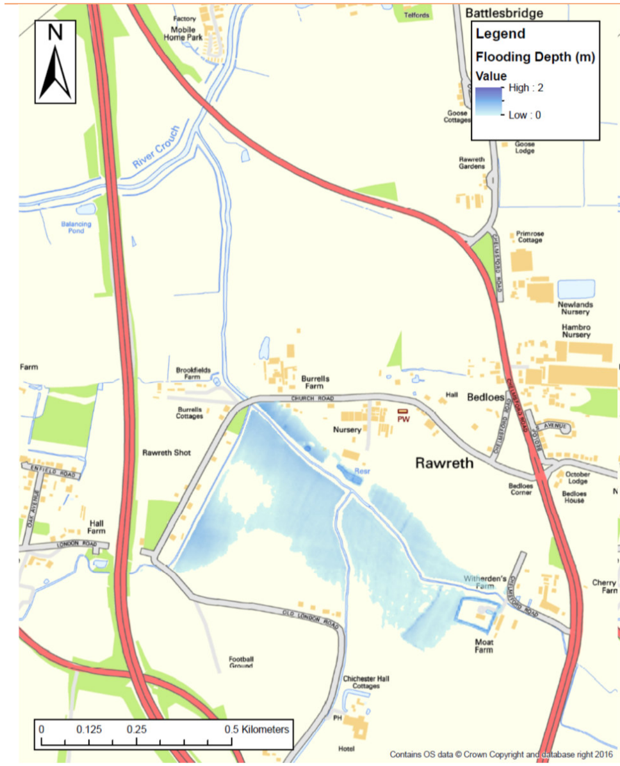

Figure 10: Option 3: 10% AEP Rawreth Brook, 50% AEP River Crouch and Highest Annual Tide (HAT)

Figure 11: Option 3: 2% AEP Rawreth Brook, 50% AEP River Crouch and HAT

Figure 12: Option 3: 1% AEP Rawreth Brook, 50% AEP River Crouch and HAT

4.4 Option 4: Re-alignment of North Benfleet Brook

The previously discussed linked 1D-2D baseline model was used to assess the impact of the proposed option. The option was schematised through the addition of a new channel with dimensions matching that of the existing Benfleet Brook. Bed levels where interpolated to provide a consistent slope to the outfall. Bank levels were kept at a constant level between the upstream and downstream extents of the channel to retain water within the channel. In order to simulate the flow diversion into the new channel the existing bridge structure was removed from the 1D channel to simulate blockage. The model was run for the three design events as below:

- 10% AEP Rawreth Brook, 50% AEP River Crouch + Highest Annual Tide
- 2% AEP Rawreth Brook, 50% AEP River Crouch + Highest Annual Tide
- 1% AEP Rawreth Brook, 50% AEP River Crouch + Highest Annual Tide

The results are shown in Figures 13-15 on the page overleaf with discussion of the results available within the main feasibility report.

Figure 13: Option 4: 10% AEP Rawreth Brook, 50% AEP River Crouch and Highest Annual Tide (HAT)

Figure 14: Option 4: 2% AEP Rawreth Brook, 50% AEP River Crouch and HAT

Figure 15: Option 4: 1% AEP Rawreth Brook, 50% AEP River Crouch and HAT

RAWRETH BROOK

Flood Alleviation Feasibility Study

JULY 2016

Incorporating

Rawreth Brook

Flood Alleviation Feasibility Study

Author	Tom de la Rosa
Checker	Aimee Hart
Approver	Phil Garvey
Report No	5001-UA008499-UU41R-03
Date	JULY 2016

VERSION CONTROL

Version	Date	Author	Changes
DRAFT	03/03/16	Tom de la Rosa	Draft for comment
FINAL	10/03/16	Donna Ryan	Edits following review and Final Issue.
REVISED ISSUE	01/07/16	Tom de la Rosa	Update including further optioneering. Modelling Technical Note appendix added.

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FIGURES

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Executive Summary

Background

Arcadis Consulting was commissioned by Rochford District Council to undertake a high level feasibility study of potential flood alleviation measures for Rawreth Brook.

The main objective of the study is to review relevant flood risk information from the Environment Agency (EA) and local authorities, in order to undertake a high level assessment of the impacts of flooding in Rawreth and identify potential flood alleviation measures.

Problem

The study has considered flooding from tidal and fluvial sources (from the River Crouch and Rawreth Brook system) and how surface water runoff within the Rawreth Brook catchment contributes to this. A key consideration within the study is the urbanised nature of the catchment at the upstream extents. As the catchment is largely urbanised, impermeable surfaces result in fairly rapid runoff, and additionally the small size of the overall catchment contributes to flows concentrating at Church Road.

Options Assessment and Preferred Option

This Flood Alleviation study has investigated four options: Option 1 investigated the installation of a tide gate and this was discounted after hydraulic modelling demonstrated that flood risk to properties from tidally influenced sources was negligible. Option 2 and 3 considered upstream storage of fluvial and surface water flows, but the initial assessment indicated the storage volumes available were inadequate to provide an acceptable Standard of Protection.

Following consultation with Rochford District Council Option 4 was developed, which diverts flood flows out of the North Benfleet Brook (the largest tributary of Rawreth Broook) upstream of the first bridge under Church Road, and conveys flow to the north of Church Road and Brookfields Farm (to re-join Rawreth Brook downstream of the Church Road Bridge).

For Option 4 the results of hydraulic modelling showed a reduction in peak flows and consequent backing-up at the Rawreth Brook / Church Road Bridge, which results in a higher Standard of Protection to properties located along Church Road. The hydraulic model was used to test what Standard of Protection could be provided and the results show that up to a 1% (1 in 100 year) Annual Exceedance Probability (AEP) event can be accommodated with some minor improvements to the left bank of Rawreth Brook and some localised road raising in the vicinity of Church Road bridge. Given the effectiveness of Option, (see Appendix A for further details) it is recommended that Option 4 is taken forward as the preferred option, as the assessment indicates the option provides a significantly improved Standard of Protection over the current situation..

Indicative costings have been provided for Option 4 and these are in the order of £800,000.

Next Steps

The high level cost estimation undertaken as part of this study provides an indication of the option cost, however it is recommended that a detailed economic analysis is undertaken in order to justify and better understand the costs and to quantify the benefits associated with Option 4. This will require further more detailed modelling and the generation of a bill of quantities for the work.

Consultation with key stakeholders including the EA and Essex County Council is required in order to address any stakeholders concerns and to understand any constraints which may affect the preferred option.

1 Introduction and Background

1.1 Background

Arcadis Consulting was commissioned by Rochford District Council to undertake a high level feasibility study of potential flood alleviation measures for the Rawreth Brook. The assessment will identify if flood mitigation schemes are viable and makes general recommendations to help manage flood risk in Rawreth and the surrounding area.

Arcadis was initially tasked with considering a tidal gate across Rawreth Brook at the confluence with the River Crouch, to restrict tidal flows up the Rawreth Brook system, together with a flood storage area adjacent to the confluence within land in the ownership of Old Burrell's Farm in order to store flood flows coming down Rawreth Brook during extreme high tide events.During development of the project the Arcadis hydraulic modelling team, using the most recent Environment Agency hydraulic model, identified that high tidal levels and high river levels in the River Crouch had a relatively minor direct effect on flooding in the Rawreth Brook at and upstream of Church Road. Following this increased understanding discussions were held with Rochford District Council and this led to a change in focus and consideration of fluvial and surface water sources. As such, an additional assessment of upstream flood storage areas to manage the principal flood risk was assessed.

Site visits were conducted on both 3rd December 2015 and 8th January 2016. Representatives from both Rochford District Council and Arcadis were present for these site visits, and representatives from the Environment Agency and Essex County Council attended the second visit. The history of flooding, possible mechanisms and potential sites for flood control structures, flood storage areas and other mitigation and control measures were discussed. Currently known or observed limitations, constraints and impacts were identified.

1.2 Location

The study area is located within the county of Essex, to the north of Rayleigh and Basildon and just east of Wickford town between Battlesbridge to the north and Rawreth to the south. The study site focuses on the confluence of Rawreth Brook and the River Crouch and the areas upstream of this location along the Rawreth Brook / North Benfleet Brook system. This area has experienced historical flooding. The confluence is located in the north west of Rawreth village and is bounded by farmland on all sides. The A1245 runs parallel to the confluence crossing over the River Crouch 50m downstream. The study area is shown below in Figure 1 and the coordinates for the confluence are E577525 N194167.

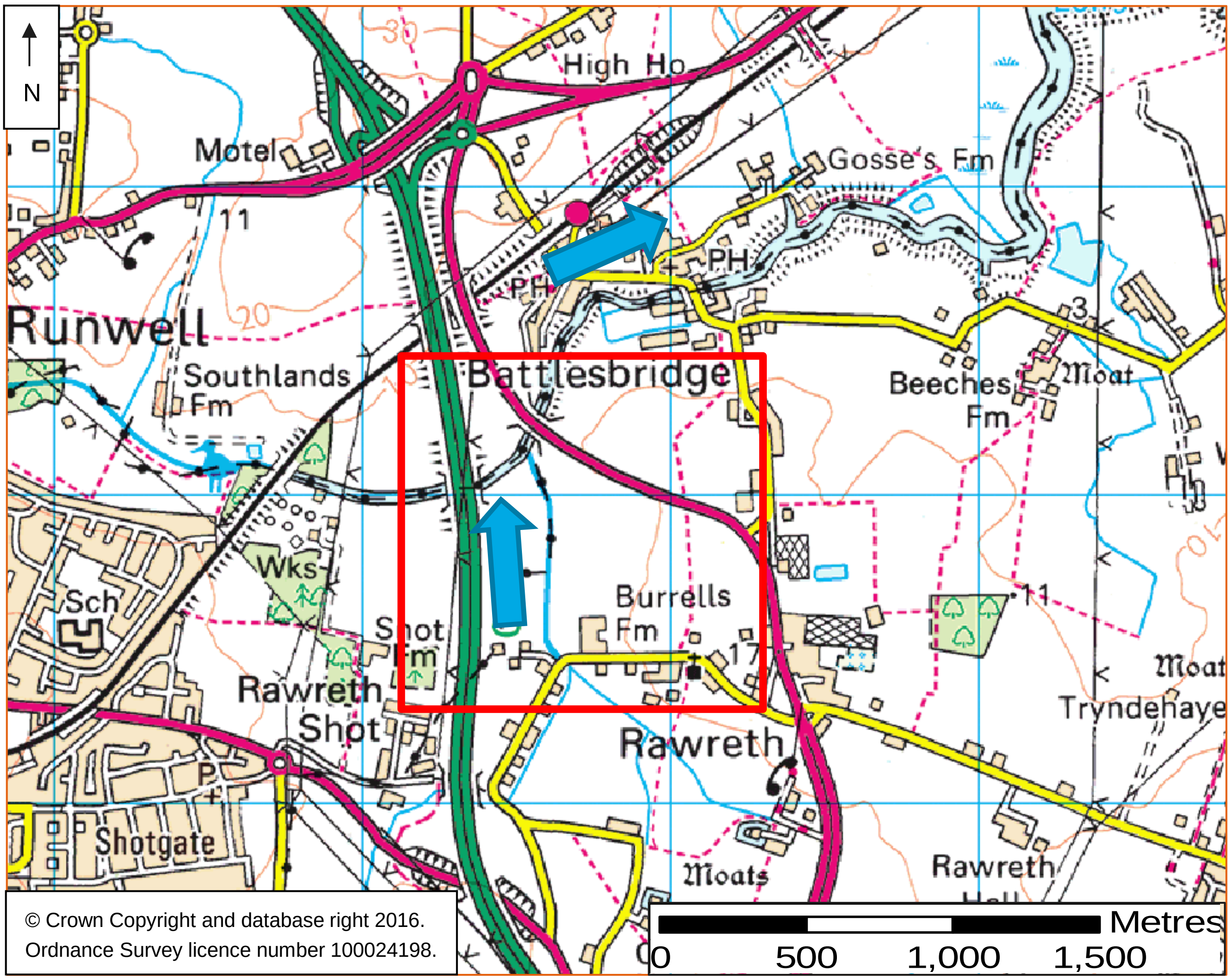

Figure 1: Site Location Map (Flow direction represented by blue arrows, study area shown in red)

1.3 Setting

1.3.1 Topography, Geology and Soils

The topography of the study area is controlled by the presence of three watercourses, the River Crouch, Rawreth Brook and North Benfleet Brook with areas surrounding the river valleys located at a higher elevation. The ground levels range from 0 mAOD to a maximum of 12mAOD. The extracted LiDAR data (which provides an indication of ground levels) for the area is shown below in Figure 2.

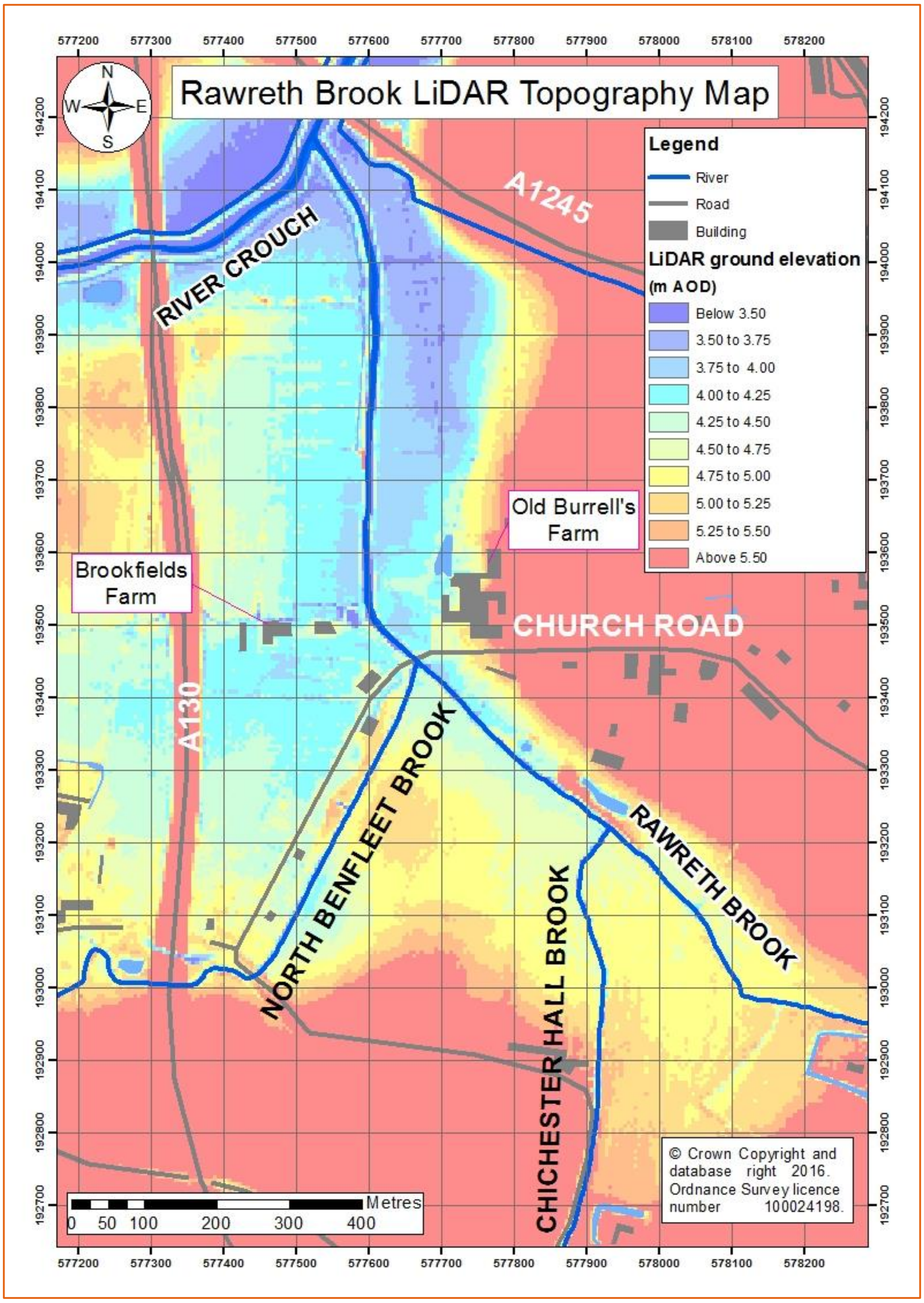

Figure 2: LiDAR Map

The Bedrock Formation underlying Rawreth and the entire study area is of the London Clay Formation (Clay, Silt and Sand). Superficial deposits adjacent to the confluence are Tidal Flat Deposits (Clay, Silt, Sand and Gravel).

Borehole TQ79SE34 (Figure 3) is the nearest in proximity to the confluence and the borehole details a stratigraphic sequence of silty clay-rich estuary alluvium with some flint pebbles and orange sandy clay lenses (grey-brown to a depth of 3m) underlain by first weathered London Clay (brown: to a depth of 3.7m) and then fresh unaltered London Clay (blue-grey: to a depth of 24m). Topsoil at the site is 0.4m thick (BGS, 2016). The same overall sequence is also observed at the 3 nearest boreholes (TQ79SE35A, TQ79SE35B &

TQ79SE18A). The only variation observed was a slight encroachment of peat and organic matter in the topsoil and immediate subsurface horizons. The implication of the geology is that it is impermeable and causes the study area to be heavily influenced by surface water.

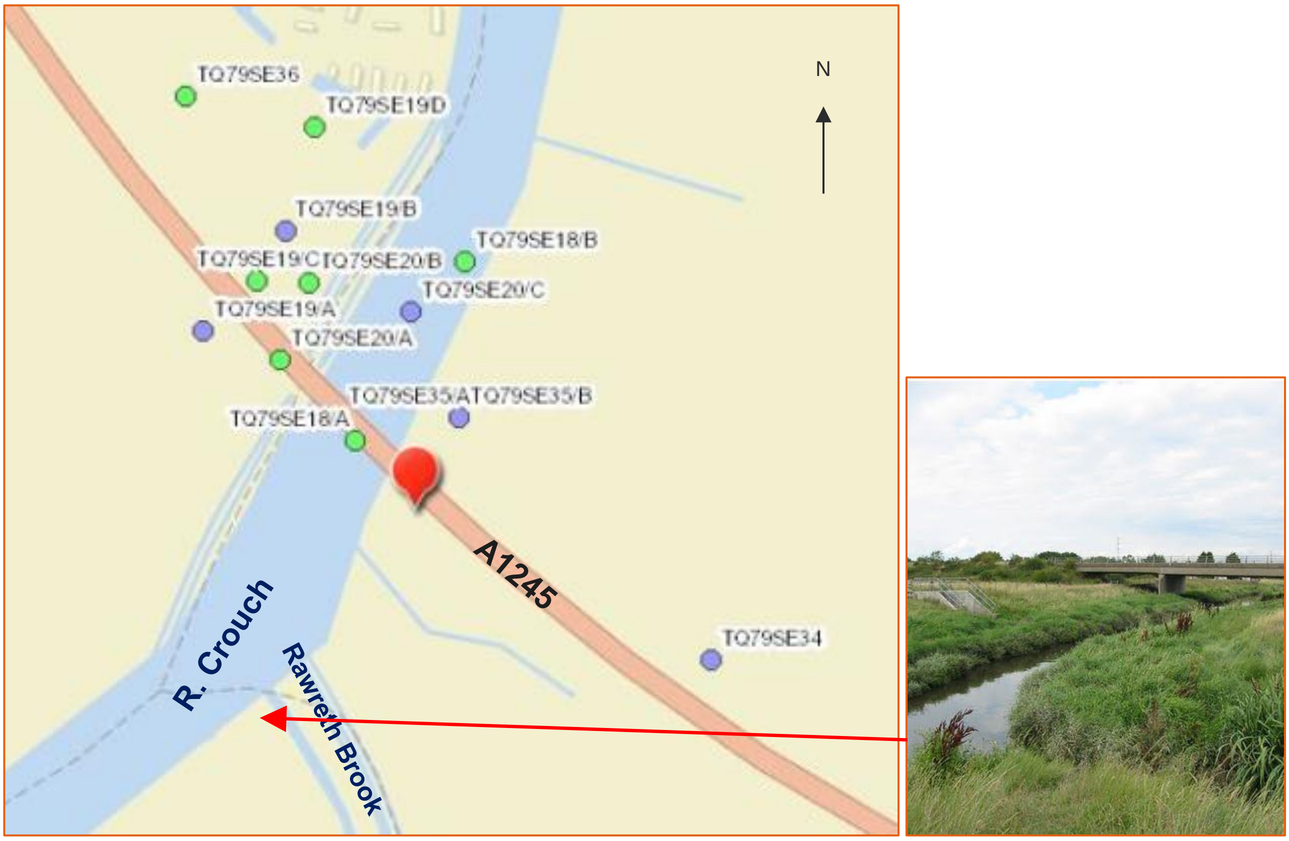

Figure 3: Borehole Map in vicinity of proposed downstream FSA site

Environment Agency mapping indicates the underlying geology forms an aquifer of unproductive strata. These are defined as rock layers or drift deposits with low permeability that have negligible significance for water supply or river base flow.

1.3.2 Major Watercourses

The study area includes the Rawreth Brook system and the River Crouch and details of the major watercourses are provided in the sections below.

1.3.2.1 Rawreth Brook

Rawreth Brook and its tributaries, including North Benfleet Brook comprise a number of small rivers draining the urban areas of Wickford, North Benfleet, Thundersley and Rayleigh at their upstream ends and more open, agricultural land with sporadic farms and residential buildings towards their downstream ends. The two main tributaries, Rawreth Brook and North Benfleet Brook, meet immediately upstream of Church Road bridge at Rawreth at grid reference TQ 77682 93430 (Figure 4). Collectively these watercourses are referred to as the Rawreth Brook system.

Figure 4: The confluence of Rawreth Brook (left hand channel) and North Benfleet Brook (right hand channel) – view upstream from Church Road bridge

At the point in Figure 4 the system is tidally influenced, and the Rawreth Brook between Church Road and the confluence with the River Crouch at grid reference TQ 77537 94157 (Figure 3) is subject to a high rate of siltation as a result. The system has an overall catchment area of 26.33 km^2 (FEH CD-ROM 3.0). Between Church Road and the River Crouch confluence both banks are elevated and the Rawreth Brook has an approximately trapezoidal channel shape, although the accumulation of tidal silt, and presence of binding vegetation (Figure 5) limits flow capacity to well below the theoretical maximum.

The Rawreth Brook system is responsive to local rainfall events, given the urbanised upstream areas. The comparatively similar size of the three main tributary sub-catchments means that a storm in the area is likely to result in peak surface water runoff translating into peak river flows which coincide at the constriction of Church Road Bridge.

Upstream of Church Road Bridge, Rawreth Brook rises at a gradient of about 1 in 500 for approximately 800m and then at approximately 1 in 300 as it approaches Rayleigh. Church Road Bridge then steepens to 1 in 250 towards the outskirts of Wickford. This suggests that surface water runoff from the urban areas, once in the watercourses, can be conveyed away from these areas relatively efficiently up to the point where runoff exceeds the channel capacity, but once the water reaches the lower-lying, more level area of floodplain it is likely to be affected by constrictions (such as the confluences between tributaries and Church Road bridge).

Figure 5: Rawreth Brook – siltation between Church Road and the River Crouch

1.3.2.2 River Crouch

The River Crouch flows for 28km through Essex and the source is at Noak Bridge. Its tributaries include Fenn Creek, Clementsgreen Creek, Stow Creek, Bridgemarsh Creek, Prittle Brook, Lion Creek but its major tributary is the River Roach. The river is fully tidal downstream of Battlesbridge Mill (grid reference TQ 78018 94619) where there is a privately-maintained traditional lock-type gate used for impounding the river to drive the mill. However, this is understood from discussion with local residents to be infrequently used and the river upstream of Battlesbridge is tidally influenced, including the downstream reaches of Rawreth Brook. The confluence of Rawreth Brook with the River Crouch is approximately 800m upstream of Battlesbridge Mill with no significant change in water level between the confluence and mill under normal flow conditions. East of Battlesbridge the tidal flow around the creeks enriches the estuary habitat permitting oyster cultivation and fish spawning. The Crouch and Roach estuaries are recognised to have international importance for wildlife (waders and wild fowl). In the vicinity of the Rawreth Brook confluence both banks of the River Crouch are elevated (Figure 6).

Figure 6: Embankments along the River Crouch, immediately downstream of the Rawreth Brook confluence (see text for arrow).

1.3.3 Existing Infrastructure

It was observed during site visits conducted on both 3rd December 2015 and 8th January 2016 that the area on the east (right) bank of Rawreth Brook near to the confluence with the River Crouch is currently drained via a series of land drains leading to a ditch running north-west. There are ditch culverts under the existing embankment (arrowed in Figure 6) and outfalls to the River Crouch through a large flap gate. The farm area to the south (Old Burrells Farm) is drained via small ditches outfalling into the Rawreth Brook, with smaller flapgates. These are frequently affected by siltation and require regular attention from the riparian landowner. There is an existing outfall on the left bank of the River Crouch opposite the Rawreth Brook confluence. A pond currently exists close to Old Burrells Farm (see Figure 2 for location).

Tidal gates exist to the north of the study area which protect the village of Battlesbridge, these are manually operated wooden gates which are assumed to be operated during periods of extreme tides.

1.3.4 Biodiversity, Flora & Fauna

Nearly twenty-five thousand water birds visit the estuary each year including nationally important numbers of shelduck, shoveler and black-tailed godwit and internationally important numbers of dark bellied Brent Geese. The Essex Coast provides over-wintering for around one fifth of the world population of dark bellied Brent Geese with an average peak of just over 6 thousand birds (about 2.5% of the world population) congregating around the Crouch and Roach estuary. The tidal flats, saltmarsh and coastal grassland and ditch systems also support thirteen species of nationally scarce plant and important populations of rare invertebrates. An important breeding population of grey seal can be found at the mouth of the crouch estuary. Consequently the area is subject to a wide range of international, national and regional designations, the Crouch and Roach Estuary is a Site of Special Scientific Interest (SSSI), a Special Protection Area (SPA) and a Ramsar (wetland) site (Burnham.org, 2016). These designations commence downstream of Battlesbridge and there are no designations applying to Rawreth Brook in the vicinity of Rawreth village.

1.3.5 Population, Land Use and Communities

Rawreth is comprised of a population of approx. 5000 people. This population is clustered around Rawreth Village centre with the majority of the population falling within the catchment of the Rawreth Brook. The area is dominated by agricultural land interspersed with towns and villages with some industrial buildings. It is an area with a growing population, and a growing demand on transportation networks and housing. There are currently plans for almost a further 1500 homes across Rawreth and Hullbridge. The local community (via Rawreth Parish Council) are keen to address the threat flooding posed to the road network, especially as the roads are to become even more critical with the influx of new residents. Following the eviction of travellers from Dale Farm the local community are keen to prevent illegal occupation of public land. It is worth noting that if travelling communities are present in the area their population could also be at risk if flooding occurs. Although mitigation of unplanned residences are not within the remit of the proposed options below.

The local community (via Rawreth Parish Council) are also active in enforcing appropriate use of public space as regards illegal grazing (e.g. prompt reporting and action of horses illegally being kept in the community garden). This demonstrates a great deal of grass roots involvement in environmental quality, regulation, enforcement and community protection schemes. This suggests that if stakeholder engagement is properly managed, the outcome will be productive. The records of Rawreth Parish Council attest to previous stakeholder engagement between the Environment Agency and local residents with regard to flooding issues (2011).

Within the study area the properties that will benefit from the flood mitigation works have low levels of deprivation. Rawreth is located within the Rochford ward and this is within 60% of the least deprived Lower Super Output Areas in England.

1.3.6 Climate Change

Climate change means that Rochford will likely experience warmer and wetter conditions than it currently expects. A warmer wetter climate will mean a higher overall amount of precipitation; the latest scientific research suggests that in the UK this will manifest as more severe and frequent storms, rather than just more days of rain at the current rainfall intensity. This means the potential for more frequent and more severe flood events. Sea levels are also expected to rise (scientists are still refining estimates) but this will undoubtedly contribute to flooding in coastal and tidally-linked catchments. Of course there is always the possibility of storms coinciding with high or spring tides. This leads to flood events in the area with both surface water/fluvial (rivers and surface run-off) and tidal components. In a warmer, wetter, more frequently stormy climate this probability increases and the likelihood of a flood influenced by both factors affecting the Rawreth area is greater.

1.4 Current Approach to Flood Risk Management

Principal flood risk management in the study area involves positive drainage of hard-standing areas along with traditional land drainage. Some areas of Greenfield land as well as developed areas drains to the public sewer system. However, it is generally accepted that the existing drainage regime is not sufficient, with surface water runoff frequently reported.

The study area is covered by the EA's Flood Warning Area "Tidal River Crouch from Creeksea to Battlesbridge" and warnings should be provided by EA. The warning area provides advanced warning for tidal and fluvial events within the study area. There is no formal flood warning system for surface water flood events.

Rochford District Council deploys sand bags to residential and commercial properties during flood events. There is currently no other active intervention to manage the probability or the consequences of flood risk.

It is considered that the flood risk posed to the community within the study area is unreasonable and therefore action is required to increase the standard of protection within the study area. This current approach is retro-active and as such does not remove the communities which are at risk.

1.5 Relevant Stakeholders

At this high level stage it is important to get an understanding of those who may be involved and affected by any schemes proposed, however we have not yet sought their views on the potential scheme. Stakeholders include:

- Rochford District Council
- Rawreth Parish Council
- Environment Agency
- Old Burrells Farm/Rawreth Equestrian Centre
- Local Residents
- Local Business Owners
- View Garden Centre
- Rawreth Industrial Estate
- Battlesbridge Parish Council
- English Heritage (church and other listed buildings)
- Essex County Council Highways (A1245)
- Basildon Council (re:Wickford)
- Hullbridge Parish Council

1.6 Data Review and Methodology

Following consolidation of the available data a review was undertaken to assess its suitably for the study area including coverage and age. Due to the relatively recent studies undertaken within the study area all data was found to be satisfactory to inform this modelling study.

1.6.1 Available Data

The following catchment information and data was provided by Rochford District Council, Essex County Council and the Environment Agency and used by the study:

- LiDAR data
- OS Maps
- OS Mastermap data
- Anecdotal evidence of flood history
- Hydrometry data
- Historic data of the Rawreth Brook and River Crouch
- Environment Agency Unit Cost Database
- Cost estimates from suppliers of flood defence components, e.g. flap valves

1.6.2 Hydraulic Modelling Methodology

A summary of the methodology used as part of the hydraulic modelling is outlined below, more detail is provided in Appendix A.

1. Gather and review existing information as detailed above.
2. Establish a ‘do nothing’ baseline for the three design events (10% AEP, 2% AEP and 1% AEP) to be used to compare the effectiveness of the proposed options. For this study the ‘do nothing’ baseline maintains the current situation, with no additional intervention to manage flood risk.
3. Modify the existing baseline model for each of the proposed options and run for the above design events to assess their effectiveness in reducing flood risk within the study area in terms of extent, depth and velocity.

2 Problem Definition and Objectives

2.1 Problem Outline

Rawreth village is affected by fluvial flooding from the Rawreth Brook and North Benfleet Brook close to the confluence with the River Crouch. The River Crouch is tidally influenced at the confluence and a combination of high tides and high fluvial flows in the River Crouch are understood to result in flows backing up Rawreth Brook. Additionally surface water flooding within the Rawreth Brook catchment is also a known issue and contributes to the flooding around Church Road Bridge. The combination of these flooding mechanisms cause the residential and agricultural properties along Church Road to experience regular flooding.

Flooding of Church Road between the North Benfleet Brook and Rawreth Brook bridges has been observed as a frequent occurrence in recent years, including some property flooding of low-lying properties between the road and North Benfleet Brook. Key locations are given in Figure 7 below. A flood alleviation would provide reduce the flood risk to the community of Rawreth along with possible downstream benefits to the Crouch.

The impacts of Climate Change are well known including more frequent and severe rainfall events along with increased seal levels and fluvial flows, by taking no action the future risk of the communities at Rawreth will be at greater risk.

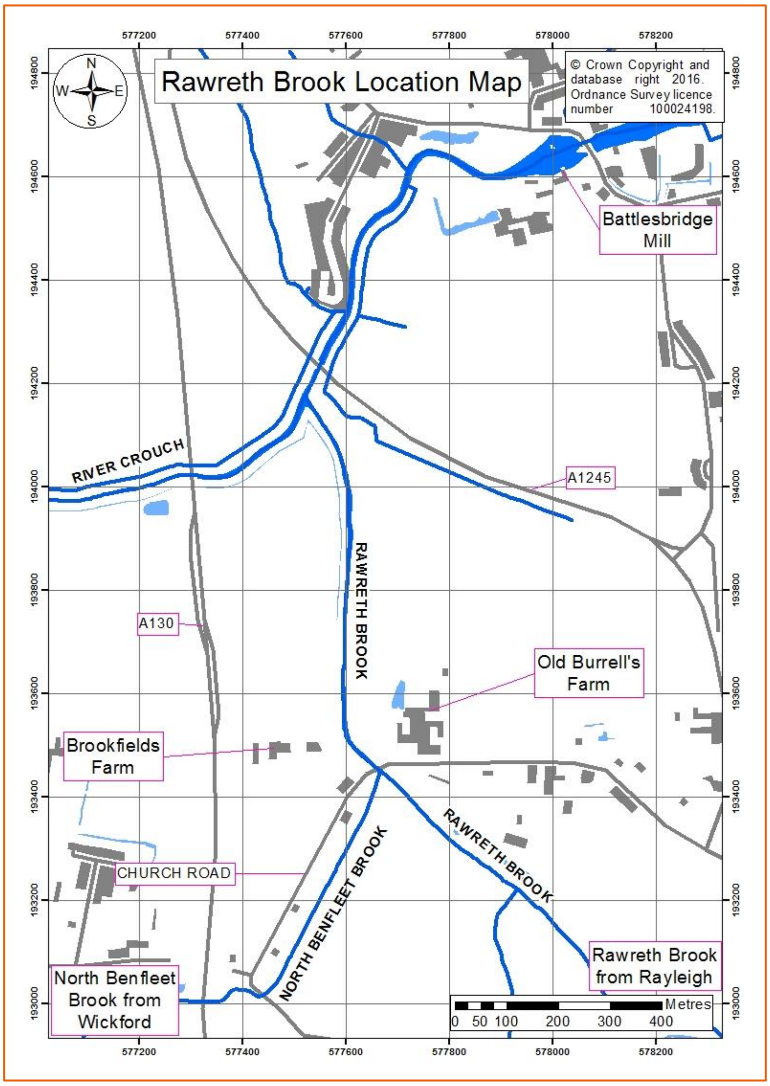

Figure 7: Site Location Map showing key points of interest.

2.1.1 Historical Flooding

Rochford District Council has provided accounts of flooding along Church Road in recent years however, no detailed mapping or reporting exist which cover the flood events. The EA Historic Flood Map does not provide an indication of historic flooding in the study area. It is considered that historic events have occurred due to a combination of the tidal, fluvial and surface water both within the Rawreth Brook and River Crouch catchments, which cause the banks to be overtopped and subsequently flood properties in this area.

2.2 Study Objectives

The aim of the study is to investigate if options are feasible (economically, socially and environmentally) to effectively reduce the effects of flooding within the Rawreth Brook catchment.

The specific objectives of the study were as follows:

- Obtain and review the relevant flood risk information from the Environment Agency and local authorities in order to undertake a high level assessment of the impact of flooding in Rawreth.
- Identify potential flood alleviation measures and undertake an assessment to determine which are the most feasible and effective solutions.
- Undertake consultation at appropriate stages with the local authorities and Environment Agency.
- Provide recommendations on a feasible solution and indicative costing.

3 Option Assessment

3.1 Initial Option Assessment

An initial option assessment was undertaken to assess a wide range of potential mitigation measures. The measures were examined to identify which measures might be feasible. This assessment is summarised in Table 1 below.

Table 1: Comparison summary for high level options appraisal for the initial stage of the Rawreth FAS.

ID	Mitigation Measure	Description	Comments	Detailed Modelling
A	Increase channel capacity	Dredge/ widen channels to increases available channel storage.	Will require unreasonable amount of maintenance due to the silty nature of the watercourses. Option not selected for further assessment.	N
B	Flood walls	Build flood walls/ embankments along channel, to extend back to 5.5mAOD contour.	High environmental and visual impact, would require extensive sourcing of earth fill material. Road / bridge raising issues at Church Road bridges across Rawreth Brook and North Benfleet Brook. Option not selected for further assessment.	N
C	Increase surface water drainage – drains	Increase capacity of upstream surface water drains.	Very expensive, will cause major disruption during works and would require water company approval. The potential upstream storage capacity within the drainage system is limited by the small catchment size. Pipes would need to be upsized at a major scale which is not feasible for this catchment size. Option not selected for further assessment.	N
D	Increase surface water drainage – open channels	Increase capacity of local drainage (field drains etc.) into watercourse.	Would require a large extent of remedial work, this would have associated land access issues and costs. This would increase the rate of runoff from the upstream catchment and concentrate the flood peak, potentially increasing flood risk at Church Road. Option not selected for further assessment.	N
E	Create floodwater storage areas	Preferentially store floodwater in an allocated storage area.	Land is available for storage for upstream fluvial flows, local surface water runoff and downstream tidal water if necessary.	Y
F	Create control structure	Attenuate flows to associated floodwater storage area and/or limit tidal/River Crouch backflow.	An active or passive control structure could potentially limit either backflows from the River Crouch or forward flows from the Rawreth Brook system or could provide a flushing storage to combat the high siltation levels.	Y
G	Change land use	Restore local areas to woodland to reduce and attenuate flows reaching the watercourses.	Area of land needed to be restored to create a significant impact is too large (majority of the farmland catchment) to be feasible. Also most of the upper end of the catchment is urbanised. Option not selected for further assessment.	N
H	Create pumping station	Pump excess volumes from Rawreth Brook to River Crouch.	Work would require siting of a suitably sized pumping station, in connection with a control structure. Whilst effective the option would be	N

			likely be very costly in terms of ongoing maintenance / energy usage. Option not selected for further assessment.	
I	Individual property-level protection (PLP)	Individual properties modified to be flood resistant.	Residents may object to modifications to their properties, modifications are potentially easy to perform and do not require major works. However, given the presence of near-surface sandy lenses in the alluvial layer high river levels may contribute to groundwater flooding in low-lying properties. Properties adjacent to the North Benfleet Brook may require more extensive protection. The frequency of recent flooding events indicates that with climate change PLP may be inadequate to the task. Option not selected for further assessment.	N
J	Tidal barrier	A control structure acting under gravity to limit tidal backflow.	It is considered that tidal flooding is not the dominant flood risk within the study area. However, the tidal barrier option has been selected to confirm this assumption and the impact of a tidal structure within the study area.	Y
K	Removing in channel constrictions	Removing constrictions within the channel to improve the conveyance of flow.	Could require a large extent of remedial work. This would improve conveyance with positive impacts upstream. Could increase flood risk downstream.	Y
L	Channel realignment	Realigning the channel to improve flow conveyance.	High environmental and visual impact. Could require a large extent of remedial work. This would improve conveyance with positive impacts upstream. Could increase flood risk downstream.	Y

3.2 Detailed Options and Modelling Assessment

Following a short-listing process detailed in Table 1, five mitigation measures were taken forward for further consideration in this assessment. Four options have been developed by combining the mitigation measures listed in Table 1. The mitigation measures have been combined to maximise the benefits and reduce flood risk.

- **Option 1 –** Tidal Control Structure and Flood Storage Area (Measure E, F and J)
- **Option 2 –** Upstream Control Structure and Flood Storage Area (Measure E and K)
- **Option 3 –** Upstream Control Structure and Flood Storage Area with enlarged Church Road bridge (Measure E and L)
- **Option 4 –** Realignment of North Benfleet Brook (Measure M)

The options are described in detail in the sections below with an overview map provided below in Figure 8.

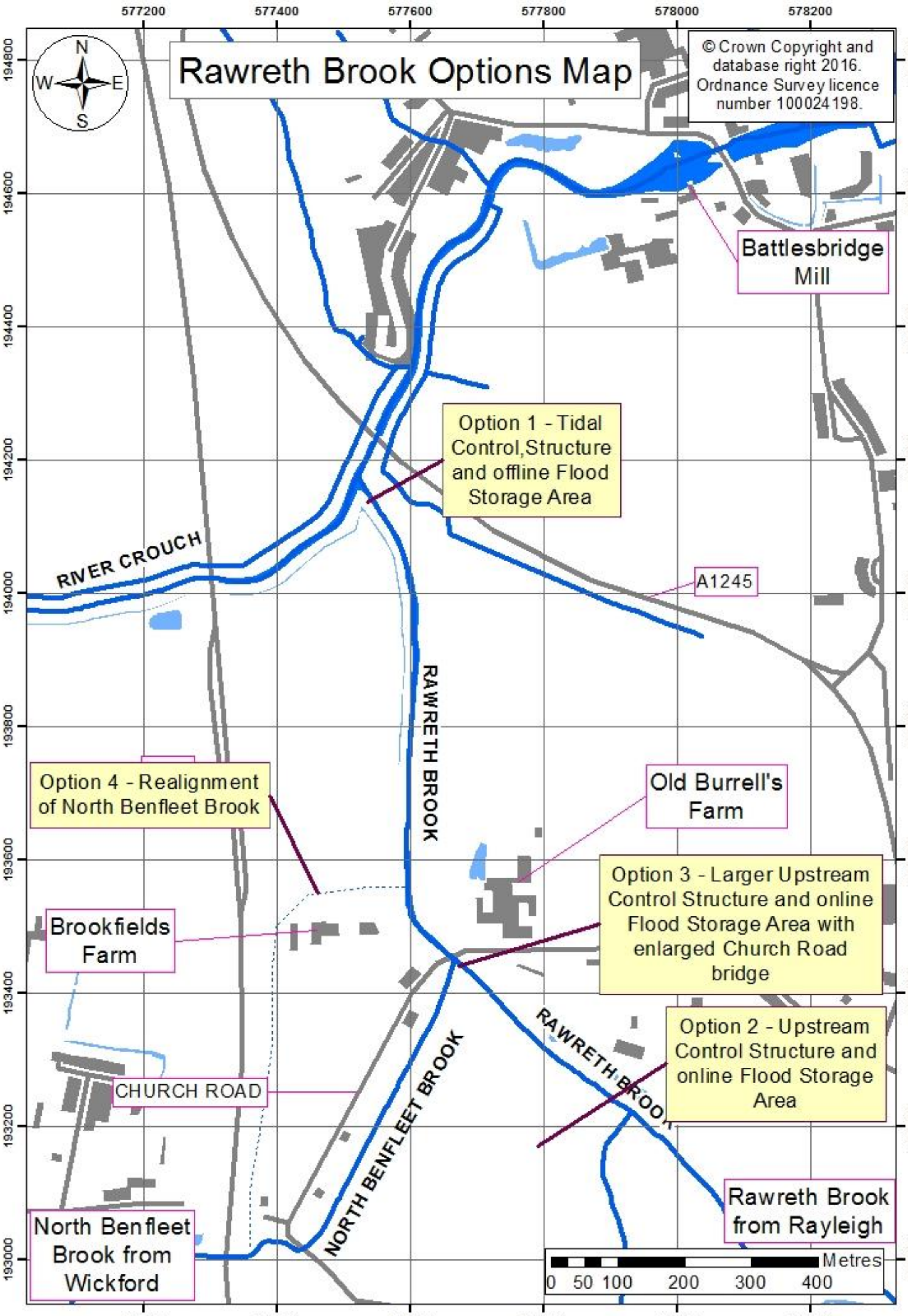

Figure 8: Feasibility Options Overview Map.

3.2.1 Option 1 – Tidal Control Structure and Flood Storage Area

3.2.1.1 Option Description

As discussed above an option incorporating three mitigation measures has been considered. The first element of this option is a control structure acting under gravity, this structure would allow one way flow from Rawreth Brook to the River Crouch to limit tidal backflow up the Rawreth Brook which is causing flooding in Rawreth village. The second element of the option is the creation of a floodwater storage area. This excavated area would be designed to preferentially flood during extreme events when the control structure is closed due to high levels in the River Crouch, and would store flows coming down the Rawreth Brook system.

This would change the siltation regime in Rawreth Brook by converting it from a tidal creek to a purely fluvial watercourse. There may be issues of stagnation upstream of the control structure during periods of tide-locking or if estuarine silts block the outfall.

3.2.1.2 Modelling Assessment

The existing linked 1D-2D Rawreth Brook and River Crouch hydraulic model was used to assess the impact of the flood alleviation option as detailed in Section 4 for two design events: 1 in 10 (10%) AEP and 1 in 100 (1%) AEP. The 1 in 10 (10%) AEP event was run for the Rawreth Brook and the 1 in 100 (1%) AEP event was run for the River Crouch, together with an annual high tide at Battlesbridge.

Analysis of the modelling results (see Appendix A) indicated that the primary influence on flooding within Rawreth village is rainfall within the catchment. The tidal influence or high fluvial levels on the River Crouch has no discernible impact on flood levels for the modelled periods, even at Church Road Bridge. Modelling also demonstrated that the proposed control structure in Option 1 might actually increase flood risk during significant fluvial flood events in the Rawreth Brook system by causing an obstacle to downstream flow, if the adjacent flood storage area is not sufficiently large.

3.2.1.3 Conclusion

As a result of the modelling assessment it has been confirmed the primary flood mechanism in the study area does not relate to tidal flooding and the principle flood risk relates to fluvial flow within the Rawreth Brook system. Therefore, it is not recommended that Option 1 is considered for further assessment, as the option has a negligible benefits and might even increase flood risk within the study area when compared to the baseline scenario.

3.2.2 Option 2 – Upstream Control Structure and Flood Storage Area

3.2.2.1 Option Description

It was observed using LiDAR ground elevation data that a relatively large flat area exists between Rawreth Brook and North Benfleet Brook upstream of their confluence at Church Road Bridge. This is entirely agricultural land and does not contain any properties at risk of flooding, although there are properties along Church Road on the left bank of North Benfleet Brook which are at risk. Constructing a low embankment along the left bank of North Benfleet Brook between the A130 embankment and the high ground by Rawreth village, running behind Bridge Cottage as indicated in Figure 9, with a control structure limiting downstream flow at the confluence, might provide adequate attenuation of flows from upstream to reduce flood risk in Church Road.

This option would involve a bund or wall 740m in length and 1m above current surrounding ground level. Due to the proximity of the North Benfleet Brook to properties in Church Road there may be a need to realign certain sections of the channel to provide adequate room for the bund. There will be a need to raise the roadway by approximately 0.5m in the vicinity of the Church Road / Old London Road junction to link in with the raised embankment to either side.

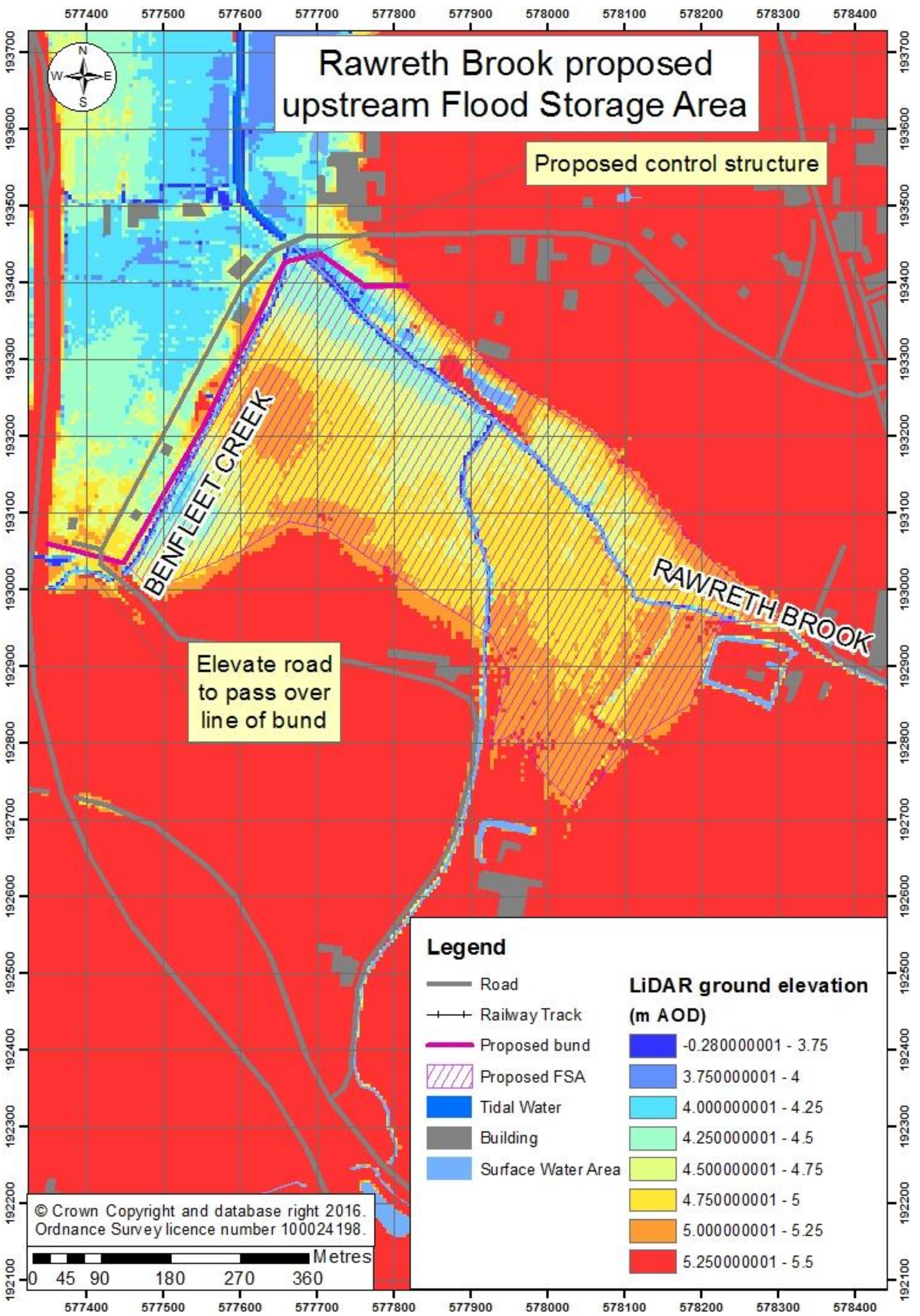

Figure 9: Upstream flood storage area location.

The control structure would be designed to limit downstream flow to the maximum capable of being passed through Church Road Bridge before spill occurs. The output of the hydraulic model gives this value as 5.6m^3/s.

The surface area of this proposed flood storage area covers 250,000m^2 and it could potentially impound 200,000m^3, which would place it well within the requirements of the Reservoirs Act. This storage area would address upstream-generated flooding, including surface runoff from the urbanised parts of the catchment, and would reduce flood risk to the properties in Church Road. If the control structure is designed to enable active control (for example a manually operated penstock) it could also be used to impound flushing volumes which could then discharge along the tidal section of Rawreth Brook at low tide and reduce the silt accumulation. However, such operation would require agreement with the landowner of the area being impounded and may have environmental implications with the expulsion of silt-laden flows into the estuary so this would require further study. An active control structure would also require the presence of staff to operate it and attract additional maintenance cost.

3.2.2.2 Modelling Assessment

This upstream flood storage area option was modelled assuming an outfall structure designed to allow the same rate of flow as can be passed under the Church Road Bridge without causing the bridge to surcharge. Church Road Bridge in the hydraulic model is represented as a box culvert with a 4m wide span and a height of 1.62m from invert to soffit, and it can pass $5.6m^3/s$ before surcharging.

The modelling (Appendix A) indicated that the properties in Old London Road would not be affected by the impoundment, although a barn at the rear of the Forge Nursery is at the edge of the area potentially flooded. The flood mechanism is backing-up from the control structure to the point where the embankment overtops. Comparison with the baseline show that some improvement of flood levels downstream of the embankment is observed, but properties are still at risk.

Raising of the embankment crest level further is not possible as this would place properties in Old London Road at risk of flooding. Therefore an option has been investigated, combining the 1m high embankment with a larger control structure and enlarged Church Road bridge. This would allow a greater downstream flow and result in a smaller volume needing to be stored.

3.2.2.3 Conclusion

Whilst the modelling results for this option did show some reduction to flood risk for the properties in Old London Road during lower order events for larger events the defences are overtopped. Analysis of the modelling indicated that the Church Road Bridge still restricts flow, this option is therefore not adequate as it does not remove any properties from the risk of flooding as compared with the baseline situation.

3.2.3 Option 3 – Larger Upstream Control Structure and Flood Storage Area with enlarged Church Road Bridge

3.2.3.1 Option Description

The embankment is proposed as per Option 2 but the Church Road Bridge is enlarged to an 8m wide span (twice the current width). The control structure immediately upstream of Church Road bridge would be set at the same aperture as the bridge so it only allows flow that will not surcharge the bridge.

3.2.3.2 Modelling Assessment

Option 3 was schematised in the same format as Option 2 however with the Church Road Bridge and box culvert upsized as per the option description.

The modelling (Appendix A) indicated that the by increasing the capacity of both Church Road Bridge and the proposed associated control structure resulted in a substantial improve for lower order return events with properties along Church Road removed from the 10% AEP maximum flood extent (see Appendix A). However the option is not suitable for the more extreme events, 2% AEP and 1% AEP with defences being overtopped.

As with Option 2, raising of the embankment crest level further is not possible as this would place properties in Old London Road at risk of flooding.

3.2.3.3 Conclusion

Whilst Option 3 provided betterment for all properties within Rawreth for lower order events (up to 10% AEP), for high order return events the defences are overtopped providing no betterment in comparison to the baseline. The two elements of this option cannot be further enhanced as they are constrained by impacting other properties within the study area and by available space. As such this option is not suitable as negligible betterment is provided when compared to the baseline situtation.

3.2.4 Option 4 – Realignment of North Benfleet Brook

3.2.4.1 Option Description

Option 4 has been considered and modelled and this option removes part of the flow upstream of the Church Road Bridge and feeds this into the Rawreth Brook system further downstream. A study of the LiDAR for the site shows a low-lying area around Brookfields Farm to the north of Church Road, and this may indicate a historic route for the North Benfleet Brook. The flows in North Benfleet Brook actually cross Church Road twice, the first time a short distance downstream from the A130 and the second time immediately following the confluence with Rawreth Brook. If a new channel could be cut diverting flows on the Benfleet Brook to the west and north of Brookfields Farm, following approximately the historic low ground, this could intercept the peak flows in North Benfleet Brook and prevent them from contributing to flooding at the pinch point of the Rawreth Brook / Church Road crossing.

This option consists of a simple channel being cut at the toe of the A130 embankment, linking North Benfleet Brook with an existing drainage ditch north of Brookfields Farm. The drainage ditch would also be enlarged. All material excavated to create this ditch would be raised as a bund along the right bank to protect Brookfields Farm and adjacent properties from flooding. A control structure would be installed at the divergence from the existing course of North Benfleet Brook to restrict flows on the existing course to an acceptable baseflow.

3.2.4.2 Modelling Assessment

The output from this model run showed a much reduced extent of flooding, but there was still a small amount of spill from Rawreth Brook at Church Road bridge and downstream from the bridge on the left bank. The model was adjusted to include a slightly raised left bank to a minimum crest level of 4.65mAOD (which is 200mm above the road surface, so a speed hump of this height would need to be included in the scheme). This was run for the 10 year design flood event and the result is shown in Appendix A.

The modelling results for the 10% AEP within Appendix A show the flood extent misses all the properties in Church Road, including those on the Brookfields Farm side, and affects only gardens in Old London Road and some outbuildings at Old Burrell's Farm. The flood extent is not greatly changed from the baseline, with no defence in place, but there is no flooding out of bank at the Rawreth Brook / Church Road bridge and the depth of flooding downstream on the right bank is reduced.

The same defence scenario was also run for a 2% AEP year and 1% AEP year design flood events, and the output is shown in Appendix A, together with a baseline plot showing the undefended case. There is a significant reduction in flood extent along Church Road, although there is some spill at Church Road Bridge near the peak of the flood.

3.2.4.3 Conclusion

The modelling has shown that Option 4 provides significant reduction in flood risk to properties along Church Road for all tested design events. Re-alignment of the Benfleet Brook is not unduly constrained with land available for a new channel. As initial modelling indicates the option could provide the highest benefit (i.e. properties with increased standard of protection), when compared to the baseline situation, it is recommended the option is taken forward for further assessment.

3.3 Option Selection Assessment

An option appraisal and comparison exercise was undertaken for the long list of options as detailed in Section 3.2 and this exercise has been summarised in Table 2.

Table 2: Option Selection Summary.

Option	Description	Taken Forward	Reasoning
1	Tidal control structure located at confluence between Rawreth Brook and River Crouch. Flood storage area to the north of the structure proposed.	No	The option has a negligible benefits and might even increase flood risk within the study area when compared to the baseline scenario.
2	Upstream control structure located beneath Church Road to limit fluvial and surface water flow. Flood storage area to the south of control proposed.	No	The option has a negligible benefits and might even increase flood risk within the study area when compared to the baseline scenario.
3	Upsized upstream control structure located beneath Church Road to limit fluvial and surface water flow. Flood storage area to the south of control proposed.	No	Whilst Option 3 demonstrated improvement over Option 2, during larger return events only very limited flood alleviation would be possible given the current configuration of the channels.
4	Re-alignment of Benfleet Brook around Brookfield Farm along with passive control structure to encourage diversion and maintain existing baseflow.	Yes	The option removes properties along Church Road from the floodplain for all three of the design events and is not unduly constrained in terms of space. Given this information this option has been selected as the preferred option as part of this feasibility study.

As part of this feasibility study high level cost estimation has taken place for the preferred Option 4 as per the above table, this is available in the following section.

4 Costing

As part of this high level feasibility study a cost estimation has been undertaken using values and case studies from the Environment Agency's Unit Cost Database (UCD) contained within "Delivering Benefits Through Evidence: Cost estimation for fluvial defences – summary of evidence" (Environment Agency, 2015). Where relevant, highways works costs have been estimated using SPON'S Civil Engineering and Highway Works Price Book. Roughly speaking costs can be divided into two main categories, capital costs and operation/maintenance costs.

As the hydraulic analysis of the proposed options found that only Option 4 is effective in alleviating the flooding experienced by Rawreth Village, a preliminary costing exercise has been undertaken for Option 4 only.

4.1.1 Option 4 – Realignment of North Benfleet Brook, with raising of Rawreth Brook left bank embankment and road crossing at Church Road bridge to 4.75mAOD

As described above in terms of costing there are four main elements which can be costed for this option:

- 710m long new trapezoidal channel of 14m^2 cross-section and construction of 710m long bund adjacent to channel using 10,000m^3 of spoil excavated from the channel and compacted.
- Simple passive control structure to redirect high flows in North Benfleet Brook into the new channel and limit flows passing along the existing channel.
- Raised section of Church Road by 0.3m over a section of approximately 30m (including approach ramps at 1 in 40)
- Raised 130m of the left bank of Rawreth Brook by approximately 500mm involving 250m^3 of new material.

The elements are individually costed dependant on their high level design requirements as below.

4.1.1.1 New Channel and Adjacent Bund

As discussed previously the preferred option includes the construction of a new earth (non-lined) channel of length 710m. For the purpose of this proof of concept a channel width of 6m has been assumed. Indicative costs per metre have been provided as part of the EA's *Cost estimation for channel management, 2015*. These indicative costs have been based on *'out-turn costs from a total of 19 projects to construct new channels and include all associated works such as excavation, formation, turfing/seeding, and disposal of material.'* As such there are many assumptions associated with the provided costs and these should be taken as indicative with detailed costing required at a later design stage. They are however suitable for a high level appraisal such as this Feasibility Study.

The EA has provided costs per metre for several different channel lengths, ranging from 50m to 2500m. The relevant lengths for this project have been extracted from the table and provided below.

Table 3: Unit costs for new earth channel construction, adapted from Environment Agency (2007). N.B. prices have been adjusted for inflation.

Length (m)	Cost per metre (£)
500	810
1,000	405

Given that the preferred option is to provide a new channel of length 710m the indicative costs will be located within the range above.

For 710m new earth channel: **£287,550-£575,100.**

It is important to note that the exacted channel material will not be require to be disposed of off-site, this can account for a significant cost, therefore actual costs are likely to be lower than those identified above which are inclusive of off-site disposal.

The second element of the preferred option involves utilising the excavated material from the new channel to create a flood bund along the right hand bank of the new channel to provide additional flood protection. As this costs will be in addition to the works costed above it is not appropriate to use the EA cost database as these will drastically over-estimate the costs by treating t at a separate project. The costs have therefore been estimated using the SPONS Civil Engineering and Highways Works cost book, it should be noted that these costs do not include site management costs as they are assumed to be included in the above. The costs have been calculated by assuming the fill required will be 10,000m³.

Table 4: Cost estimation for bund deposition and compaction, modified from SPONS 2012. Note prices have been adjusted for inflation.

Works Element	Unit	Total Rate (£)	Total Cost (£)
Deposition of fill	m^3	0.92	**92,00**
Compaction of fill	m^3	2.1	**21,000**
Total	m^3	3.02	**30,200**

The total estimated cost for this element of work including the channel excavation and new bund creation is estimated at **£317,750-£605,300**.

4.1.1.2 Control Structure to divert high flows in North Benfleet Brook

In order to ensure adequate flows to both the existing North Benfleet Brook and the new proposed channel a simple weir structure in proposed is proposed at the Church Road Bridge. The costs have been estimated using the EA's *Cost estimation for control assets – summary of evidence* and have assumed that simple structure spanning approximately 6 metres. The EA's Unit Cost Database identifies the cost as **£9,315** for a fixed weir of width 5-20m.

4.1.1.3 Church Road Raising

The third element of civils work of the preferred Option 4 is the raising of the circa 30m section of Church Road by 0.3m in order to limit flood event extents. At this high level stage costs have been estimated per metre as per the 'Approximate Estimating Rates' section of SPON'S Civil Engineering and Highway Works Price Book,. Church Road is classified as a rural two lane link road with approximate total width of circa 11m. The following estimated cost is provided for this road:

Rural two lane link road: £1001 / m

For the section of works of 30m the overall cost is estimated at approximately **£30,030** inclusive of incidental items and labour.

4.1.1.4 Rawreth Brook Bank Raising

The fourth element of civils work within the preferred option is to raise circa 150m of Rawreth Brook's left bank by 500mm in order to limit overbank flow during flood events, this raising would be linked with the Church Road works in order to provide a continuous barrier. As these earthworks are separate to the new channel raising it is appropriate to use the EA's Unit Cost Database in order to provide high level costs. The following table has been taken from the EA's *Cost estimation for flood storage (2015)* and provide a high level indicative cost for earthworks as part of flood protection schemes. For the work involving 250m^3 of embankment volume the following cost has been identified:

Table 5: Indicative costing for new embankment construction. Adapted from EA Cost Estimation Guidance (2015).

Volume Band	Average Cost per cubic metre (£)	Total Cost (3)
<500 m^3	235	£58,750

The total estimated cost for this element of work is estimated at **£58,750.**

4.1.1.5 Total construction cost estimate

In line with Environment Agency guidance for feasibility stage studies, we will include an optimism bias (contingency) of 60% to allow for uncertainty in costing.

This gives a total project construction cost of:

Table 6: Total of construction costs

Flood Alleviation Works Element	Cost
New channel and embankment (weighted 75% lower end)	£389,638
Control Structure in North Benfleet Brook	£9,315
Raising of Church Road	£30,030
Rawreth Brook bank raising	£58,750
Sub-Total	***£487,733***
Contingency - Optimism Bias (60%)	£292,640
Total	**£780,373**

4.1.2 Operation and Maintenance (O&M) Costs

It has been assumed the raised road and the new Church Road Bridge will be adopted by the local Highways Authority who would take on responsibility of these assets, therefore maintenance costs are not provided for these elements of the proposed option. Ongoing operation of flood defences and maintenance of embankments incurs costs. Failure to address maintenance requirements as part of the design can lead to:

- the risk of asset failure
- higher long-term costs.

For the Rawreth FAS the O&M costs are envisaged to include:

- annual inspections
- vegetation removal

As the proposed option only adds one new element in terms of structures, the new channel only this item has been assessed for indicative operation and maintenance costs.

As per EA cost estimation guidance annual costs for operational and maintenance of fixed weirs is not anticipated, therefore these costs have been ignored for this high level study.

4.1.2.1 New Channel

Embankment maintenance cost estimates are provided by the EA and are detailed below:

Table 7: Open channel maintenance costs. Adapted from EA Cost Estimation Guidance (2015).

Target Grade	Manual Clearance cost (£/km/year)	Rawreth Ditch Cost (£/year for 710m channel)
2	3,424-30,667	2431-21,774
3	1,240-25,132	880-17,844
4	859-6,092	610-4,325

EA guidance states that the following factors should be used for embankment maintenance costing:

Difficult access: 2

Invasive weeds: 1

Protected species: 1

The site is relatively rural however access is not a major issue therefore it is predicted that the maintenance costs of the Rawreth FAS will be towards the lower end of the ranges in Table 5. For this high-level feasibility costing we will assume **£1,200** per annum.

5 Conclusions and Recommendations

5.1 Conclusions

In accordance with the commission from Rochford District Council, Arcadis Consulting has undertaken a high level option appraisal in order to develop options to alleviate the flooding currently experienced within Rawreth Village during periods of intense rainfall, which result in high flows in the receiving watercourses and localised surface water flooding.

As per the project brief this study has analysed four options for alleviating flooding within Rawreth in terms of feasibility and effectiveness:

- **Option 1** comprised of a tidal flap gate in order to limit the influence of the River Crouch along with a flood storage area to contain flood water from Rawreth Brook during flood events.
- **Option 2** comprised of upstream flood storage area with an associated bund and manual flow control structure.
- **Option 3** combined Option 2 with an enlarged bridge under Church Road to improve downstream flow conveyance and remove the resultant constriction leading to the predicted flood bank overtopping.
- **Option 4** diverted North Benfleet brook from just downstream of the A130 to pass north of Brookfields Farm, with only a limited low flow allowed to be used within the original channel.

Hydraulic modelling was undertaken for all options in order to assess their effectiveness at reducing flooding within Rawreth Village with the following results:

- For Option 1 the modelling concluded that the tidal influence from the River Crouch on levels within Rawreth Brook is extremely limited, when the tidal control structure was modelled the areas upstream flooded as per usual from fluvial flooding from the upstream watercourses. This indicates that the primary source of flooding was surface water runoff and rainfall within the Rawreth Brook catchment upstream of Church Road, dictating fluvial flows in the impacted watercourses.
- Option 2 was then modelled to establish the effect on the downstream water levels during extreme rainfall events. The detailed modelling established that an upstream flood storage area would reduce downstream flooding, but not sufficiently on its own. Church Road Bridge was still functioning as a constriction to flow which was leading to excessive backing-up of flood water, causing road and flood bank overtopping.
- Option 3 then built on Option 2 but included an enlarged Church Road bridge to enable the passage of greater downstream flows on the Rawreth Brook, limiting overtopping of the existing road and proposed flood bank.
- Option 4 allowed the full flow from Rawreth Brook to pass under Church Road Bridge without flood attenuation, but the component of flood flow from North Benfleet Brook was completely removed from the Church Road bridge bottleneck through a new diversion channel. This greatly reduced the out-of-bank flooding at Church Road Bridge.

Following analysis of the modelling results (Appendix A) Option 4 has been taken forward as the preferred option, as the option provides the highest benefit and when compared to Options 1-3 the option has minimal of constraints. The initial modelling indicates that Option 4 provides a 2% (1 in 50 year) Standard of Protection.

To progress this option further a detailed assessment of the associated benefits and costs is required. In addition it will be necessary to engage with additional landowners to those already consulted and to undertake a further walkover of the proposed route for the diverted channel. A greater Standard of Protection could be achievable but this is likely to require a flood gate across Church Road, (the system would not be entirely passive with the addition of a flood gate).

An indicative costing exercise has been undertaken for Option 4, this concluded that for the four main elements of work associated with the option (new channel and embankment alongside the channel, passive control structure, raising earth bank along section of Rawreth Brook and raising a section of Church Road) that the total estimated capital cost (including optimism bias) is **£780,373.** Maintenance and operation costs have been estimated for the embankments as **£1,200 / year** in order to maintain EA Grade 3.

5.2 Recommendations and Next Steps

- A conservative approach has been used when estimating costs; during the next stage of work is recommended that a quantity surveyor produces bill of quantities to provide more accurate costs. These may need to include for a sheet pile or clay core cut-off along the raised river banks.
- Although the existing hydraulic model has been used and is considered to be good quality, it is recommended that more detailed modelling is undertaken in any future stage of work, in order to fine tune the design and confirm the optimum standard of protection that can be provided.
- In order to secure funding for flood protection works economic justification needs to be undertaken, the initial results produced as part of this high level assessment indicated that a relatively low number of properties would benefit given the alleviation costs. It is recommended that economics analysis is undertaken to provide guidance as to the costs and benefits.
- Consultation with key stakeholders including the EA and Essex County Council is required, this should be followed with the development of the preferred option though conceptual design to detailed design.

APPENDIX A

Rawreth Modelling Technical Note

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